

# Influence of Cluster Exposure and Winemaking Processes on Monoterpenes and Quality of Golden Muscat

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**Abstract.** *Effects of cluster exposure and winemaking treatments on free- and potential-volatile terpenes (FVT, PVT), total soluble solids (TSS), titratable acidity (TA), phenols pH, color and potassium were studied. Canopies of Golden Muscat grape vines were manipulated by shoot positioning and basal leaf removal at fruit set to create shaded and exposed cluster conditions. Winemaking treatments included: control, 4-hr skin contact prior to press, freeze concentration of must, and addition of  $\beta$ -glucosidase after fermentation. At harvest, exposed fruit had higher PVT levels in the pulp and skin fractions, and shaded grapes had lower FVT levels in the skin and pulp fractions. Accumulation of FVT and PVT differed between exposed and shaded fruit and between skin and pulp fractions. Exposed fruit contained more phenols and TSS and less TA than shaded fruit, and these differences remained in the wines. Wines made from exposed fruit contained greater FVT and PVT than wines from shaded fruit. Addition of  $\beta$ -glucosidase increased FVT. Other winemaking treatments had inconsistent effects on PVT and FVT levels.*

## 1. Introduction

The flavors and aromas of grape cultivars are responsive to seasonal differences, viticultural practices and winemaking practices. Increased light interception by grape clusters has been associated with improvements in must and wine quality (Morrison and Noble, 1990). Increased fruit exposure can be achieved by leaf removal in the fruiting zone of the canopy, repeated combings and shoot positioning of the vines. This exposure increases light interception and daytime temperature of fruit: factors that may contribute to compositional differences between shaded and exposed fruit (Ruffner et al., 1976). Smith et al. (1988) and Reynolds and Wardle (1989a) observed an increase in free-volatile terpenes (FVT) and potential-volatile terpenes (PVT) in response to greater cluster exposure. In some cultivars, Muscat, Riesling, Gewurztraminer, etc., the ability to predict and regulate monoterpenes, the major flavor and aroma compounds of grapes and wines, would benefit the wine industry by maximizing the wine potential of grapes.

The objective of the study was to examine the response of fruit of Golden Muscat, a white hybrid cross of Muscat Hamburg (*Vitis vinifera* L.) x Diamond (*Vitis labrusca* L.) to shaded and exposed light conditions on the potential- and free-volatile terpenes and on fruit chemistry.

## 2. Materials and Methods

**Field Treatments:** The Bilateral-cordon trained, three-year-old Golden Muscat vineyard is located at the University of Arkansas Main Agricultural Experiment Station in Fayetteville. Vine spacing was 1.8 m in north-south oriented rows 2.7 m apart. A randomized complete block design, consisting of 4 replications with 4 plants per replication, was used for 2 cluster exposure treatments.

The canopy was manipulated to create shaded and exposed cluster conditions. At fruit set, clusters were exposed by the removal of the two most basal leaves on all shoots. Weekly, from fruit set to harvest, shoots were gathered and then loosely fastened in a manner that shaded clusters. Exposed treatments were shoot positioned weekly in order to maintain exposure. Exposed and shaded clusters received 58 % and 48%, respectively, of total available light. Videography was used to measure cluster radiation exposure (Stutte et al., 1990; Stutte and Stutte, 1988).

**Berry Composition:** Two clusters, representative of the respective treatments, were collected weekly from each replicate from veraison to harvest (a total of 4 sampling dates). All grapes were removed from the cluster. A random sample of berries was juiced through a Squeeze strainer (Lemra Products, Woodbury, CT) to make 100 mL of juice for use in the following determinations: color, total soluble solids (TSS), pH, titratable acidity (TA), potassium and phenols. The remainder of the berries were frozen whole and saved for FVT and PVT determinations.

Color was measured on a Gardener Color Difference Meter (CDM) (Pacific Scientific, Silver Springs, MD) standardized to  $L=92.4$ ,  $a=1.0$  and  $b=1.0$ . Total soluble solids were measured on a Reichert Abbe Mark II refractometer (Bausch and Lomb, Ins., Rochester, NY), and the pH was measured with an Orion EA 920 pH meter (Orion Research Ins., MA). A 5-mL sample in 126 mL of deionized water was titrated with 0.1 N NaOH to an endpoint of 8.2 pH. Titratable acidity is expressed as percentage tartaric acid. Juice potassium was determined by atomic absorption with an Instrumentation Laboratories Ins. model 251 atomic absorption-emission spectrophotometer (Thermo-Jarrell Ash Ins., Franklin, MA).

Phenols were determined by the Folin-Ciocalteu method (Slinkard and Singleton, 1977). A correction factor was subtracted from phenol readings due to false increases caused by sugars (Singleton, 1973). The correction factor was obtained by performing the Folin-Ciocalteu procedure on sugar-water solutions made from 55/45 fructose/glucose syrup at 12 to 24 percent TSS.

**Monoterpenes:** FVT and PVT were quantified by the method, Dimitriadis and Williams (1984) with the following exceptions: 1) Skin and pulp fractions were separated from 75 berries, 2) 50 ml of deionized water was added to the skin portion, 3) fractions were liquefied for 30 sec in a blender and filtered through cheesecloth. Once separated, the skin and pulp fractions were prepared according to Dimitriadis and Williams (1984), and absorbance was quantified by a Bausch and Lomb Spectronic 20 spectrophotometer at 608 nm.

**Statistical Analysis:** Repeated measures analysis of variance was used to compare the effect of cluster exposure level on grape quality parameters throughout maturation. Main effects and linear, quadratic and cubic trends over time were compared between exposure levels. Comparisons were considered significant if  $P < 0.10$ .

### 3. Results and Discussion

**Berry Weight and Composition:** Berry weight was not significantly affected by cluster exposure (data not shown). However, color indices suggested delayed ripening in shaded fruit compared to exposed fruit (Fig. 1). Yellow color intensity, "b" value, was equivalent between treatments at harvest. Shaded fruit was darker (lower "L") than exposed fruit throughout the sample period.

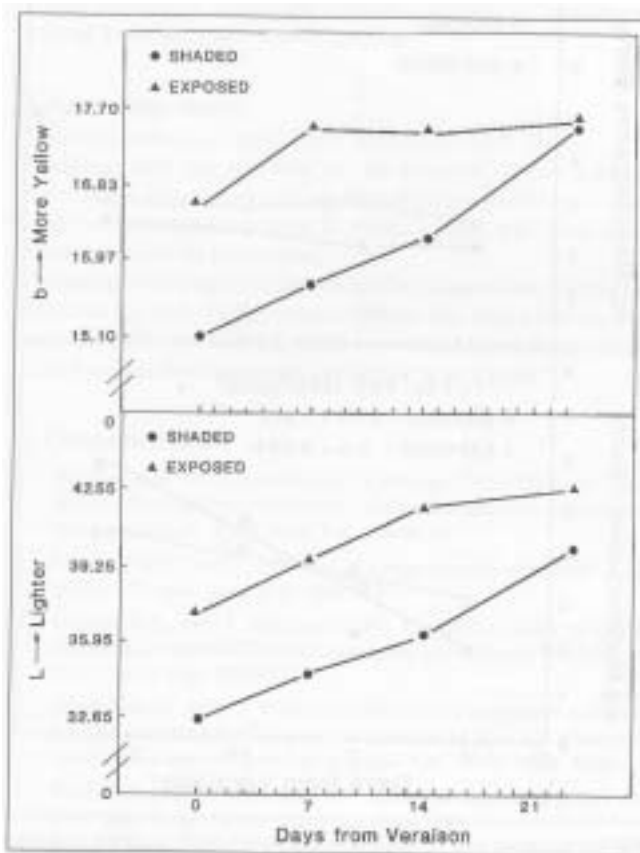


Fig. 1: Changes in "L" and "b" color values of expressed juice from shaded and exposed Golden Muscat grapes during maturation, August 5-28, 1990.  $P=0.01$ , between treatments throughout maturation.

the skin of shaded berries accounted for 89.5% of the total FVT difference between exposure treatments. Skin contact, therefore, would help liberate FVT from the skin into the juice. Pressed must from shaded fruit had higher (0.01 mg/L) FVT than did must from exposed fruit (data not shown). Daytime temperatures increased after the second sampling date, possibly enough to cause volatilization of FVT in exposed fruit (Reynolds and Wardle, 1989b). Sunlight interception and internal berry temperatures may contribute to terpene metabolic differences, but effects are difficult to separate under field conditions (Morrison and Noble, 1990).

The lower accumulation rate of TSS in shaded compared to exposed fruit ( $P = 0.01$ ) suggests delayed ripening or increased fruit temperatures in exposed berries (Bledsoe et al., 1988; Kliewer and Linder, 1968; Marais and Van Wyk, 1986). Higher TSS in exposed fruit than in shaded fruit at equivalent pH cannot be explained by delayed ripening alone (Fig. 2).

Compared to shaded fruit, exposed fruit had a pH of 0.11 units higher 14 days after veraison and a 141 mg/L greater mean  $K^+$  increase between the second and third dates (data not shown). The relationship between pH and  $K^+$  has been previously established (Iland, 1987); investigators have associated higher pH at maturity in shaded fruit with higher  $K^+$  (Rojas-Lara and Morrison, 1989). Slightly higher pH and  $K^+$  were observed at harvest for shaded compared to exposed fruit in the present study. Potassium and pH across exposure treatments were positively correlated ( $r^2 = 0.81$ ). Shaded fruit conditions may adversely affect the metabolism of pH-determining factors. Exposed fruit increased in phenol content at a higher linear rate than shaded fruit (Fig. 3) and had higher phenol content throughout the sampling period. Increased phenolic content in response to greater cluster exposure, has been previously established (Crippen and Morrison, 1986).

Skin FVT in shaded fruit increased throughout the sampling period similarly to terpene accumulation patterns observed by other researchers (Wilson et al., 1984). Contrary to work by Reynolds and Wardle (1989a), shaded fruit in this study had more FVT at harvest and a higher rate of linear increase (Fig. 4 and 5) than did exposed fruit. FVT in

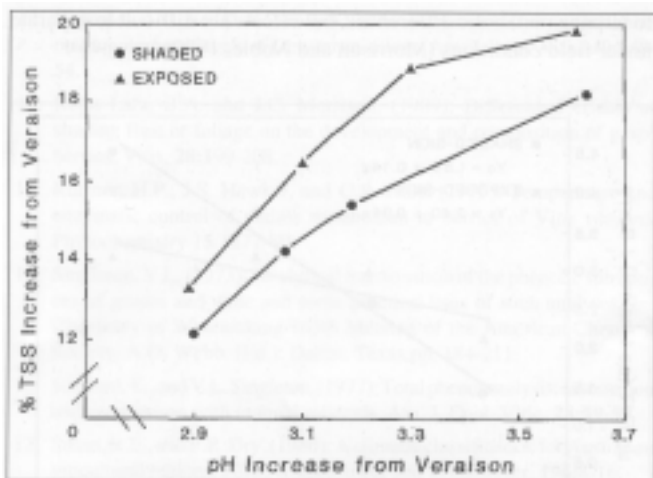


Fig. 2: % Total soluble solids (TSS) relative to pH in pressed juice from shaded and exposed Golden Muscat grapes at each sampling date (0, 7, 14 and 23 days from veraison).

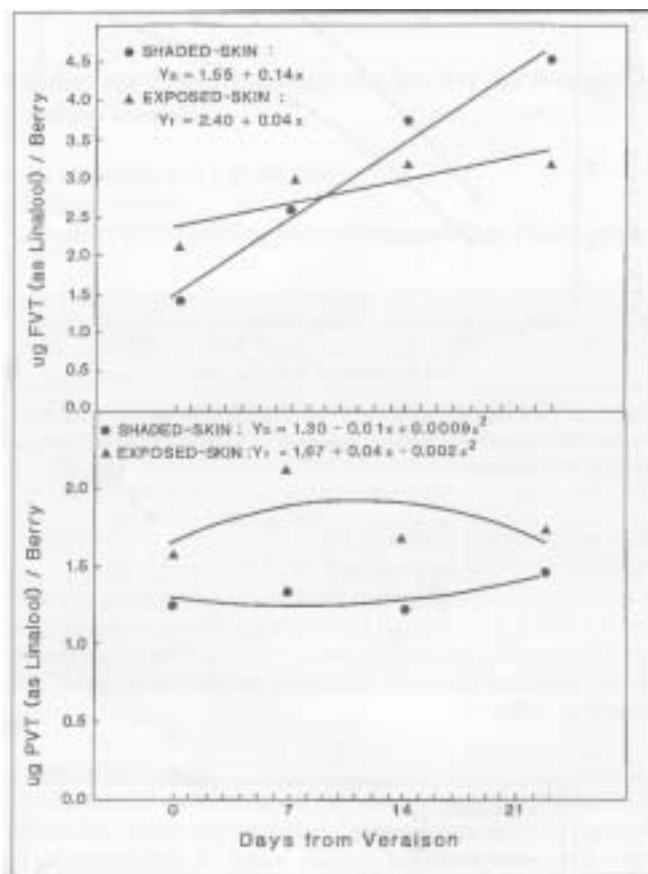


Fig. 4: Changes in FVT and PVT ( $\mu\text{g}/\text{Berry}$ ) in skin fractions of shaded and exposed Golden Muscat grapes during maturation, August 5-28, 1990. FVT in skin, between treatments 23 days after veraison,  $P=0.06$ . FVT in skin, between linear rates,  $P=0.066$ . FVT in pulp, between treatments 0 days after veraison,  $P=0.01$ . PVT in skin, between treatments throughout maturation,  $P=0.03$ . PVT in skin, between quadratic rates,  $P=0.03$ . PVT in pulp, between treatments throughout maturation,  $P=0.05$ .

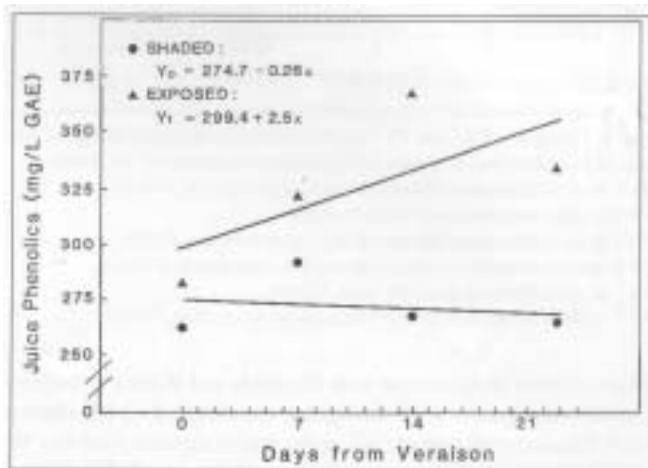


Fig. 3: Changes in phenolic content (mg Gallie Acid Equivalents/L) of expressed juice from shaded and exposed Golden Muscat grapes during maturation, August 5-28, 1990.  $P=0.03$ , between treatments throughout maturation.  $P=0.009$ , between linear rates.

Exposed fruit, in agreement with Reynolds and Wardle's findings (1989b), had greater PVT throughout maturation than did shaded fruit. The accumulation of PVT in the skin of exposed fruit may be negatively affected by warm night temperatures ( $r^2 = -0.89$ ); further increases in PVT were not observed after night temperatures increased above  $30^\circ\text{C}$ . Shaded and exposed grape-skin fractions had different quadratic responses for PVT over time (Fig. 4). Total FVT in the shaded berries was lower than that in the exposed berries at the first and second sampling and higher at third and final sampling dates. Total monoterpenes were lower in shaded fruit at the first and second sampling, the same as the exposed fruit at the third sampling and higher on the final sampling date.

Grapes were harvested after optimal ripeness. According to conventional maturity standards (pH and acid values), exposed fruit should have been harvested on the third sampling date. Previous studies have found monoterpenes to accumulate after maturity (Marais and Rapp, 1988; Reynolds and Wardle 1989a). In the present study, FVT and PVT increased after optimal ripeness in exposed and shaded fruit.

Two separate studies (Williams et al., 1984; Wilson et al., 1984) done on Muscat of Alexandria grapes in the climatically classified (Smart and Dry, 1980), hot and sunny vineyard of Glen Osmond, South Australia, identified dienediol-1, a FVT with low floral intensity (Noble et al., 1987), to be the major monoterpene of the grape. Concentrations of dienediol-1 at grape ripeness exceeded the collective concentrations of all other monoterpenes in the grape (Williams et al., 1984). Individual terpene concentrations were not quantified in the present study; however, if Golden Muscat has a monoterpene portfolio similar to that of Muscat of Alexandria, possibly high concentrations of dienediol-1 may be responsible for the high FVT to PVT ratio observed in skin-berry fractions. Decreases in free terpenes during ripening in Riesling, Kerner, and Gewurztraminer grapes grown in South Africa were attributed to warm climatic conditions (Marais and van Wyk, 1986). Reynolds and Wardle (1989a), using Gewurztraminer grapes grown in British Columbia, observed slight increases in FVT in exposed and shaded grapes over time; however, comparisons between studies are difficult due to differences in cultivar, temperatures during ripening and time interval between onset of veraison and maturity.

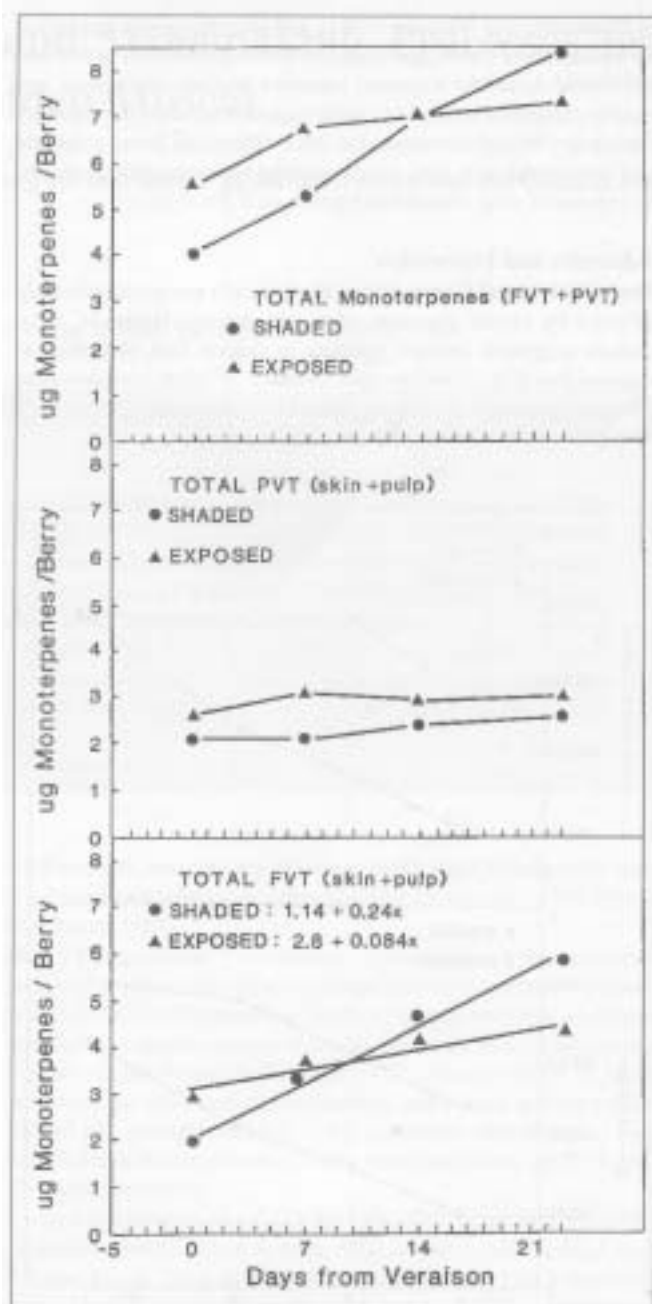


Fig 5: Changes in total monoterpenes ( $\mu\text{g}/\text{Berry}$ ), PVT, and FVT of shaded and exposed Golden Muscat grapes during maturation, August 5-28, 1990. FVT, between treatments 23 days after veraison,  $P=0.04$ . FVT, between linear rates,  $P=0.05$ . PVT, between treatments throughout maturation,  $P=0.02$ .

#### 4. Conclusions

Observed differences among TA, phenol, TSS and K' in shaded and exposed fruit agreed with results reported by Coombe (1987) and Smart and Dry (1980). Exposed fruit increased in phenol content at a higher linear rate than shaded fruit. Monoterpene response during maturation in this study was similar to responses in studies on Muscat cultivars done in South Australia and South Africa. Skin FVT in shaded fruit increased throughout the sampling period and accounted for 89.5% of the total FVT difference between exposure treatments. Increases in PVT were not observed after night temperatures increased above  $30^{\circ}\text{C}$ . Comparisons between investigations done in cool and hot climates suggest that monoterpene accumulation may be temperature related. Our study observed a greater response to shaded and exposed conditions by free terpenes located in the skin than those in the pulp.

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